South Pond - History and Investigative Summary, Occidental Chemical Company Plant Site, Ludington, Michigan

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DATE:	May 8, 2014

This memorandum provides background information on the construction, use, and investigation activities at the South Pond of the Occidental Chemical Company (OxyChem) Ludington Plant Site in Ludington, Michigan (site).

History and Use

In the 1880s, the Lyons Salt Works, Anchor Salt Company, and Morton Salt Company occupied the site. In the early 1940s, the site was operated for the U.S. Defense Department by the Dow Magnesium Corporation to make magnesium hydroxide for the war effort during World War II. The Dow Chemical Company (Dow) purchased the site in 1948 and operated it until July 2009, at which time the site was sold to OxyChem, which remains the site's current owner. The sale included the production facilities located onsite, as well as approximately 90 acres of the site on the eastern end of Pere Marquette Lake occupied by a series of retention cells known as the South Pond. As part of the sale, Dow retained certain obligations relating to the environmental conditions at the Plant Site and South Pond.

The site encompasses 183 acres within an industrialized area of Ludington, Michigan, along the northeastern and eastern shores of Pere Marquette Lake (Figure 1). The site remains in operation, manufacturing various grades of calcium chloride salt and calcium chloride solution processed from brines received from Martin Marietta Magnesia Specialties, Inc.

The South Pond is a series of retention cells constructed to hold post-process water delivered from the site for the primary purpose of residual solids settling (Figure 2). The original South Pond was constructed in 1962 by dredging Pere Marquette Lake to build outer dike walls. Between the late 1960s and 1980s, several additional treatment cells were installed (including the Secondary and Tertiary Cells), and dike walls were raised a number of times, using lime solids and fly ash from the interior of the pond as building material. Agricultural-grade lime was mined from the ponds beginning in 1982 and ending in 2005. Two of the three primary settling cells (East and West Cells) constructed inside the dikes are full of residual solids and are no longer in use. The West Cell of the South Pond was likely inactive by 1978 (date the cell was taken out of service is not known with certainty, but was sometime in the late 1970s to early 1980s) while the East Cell was filled and taken out of service in 1998, with the Center Cell subsequently becoming the only active cell receiving post-process water. A timeline of the South Pond construction and uses is provided on Figure 3.

Use of the South Pond cells historically has been primarily for residual solids settling, with the solids generated from a variety of sources. The South Pond is still in use today to settle residual solids removed during the reliming of brine feed and during the filtration of spent brine to the brine injection wells. From 1962 to 2000, the pond was used for residual solids settling of material from the lime fly ash and magnesium hydroxide production plants; these plants were shut down in 2000 and 2003, respectively. From 1962 to 1972, fly ash from the site power house was sluiced to the pond for disposal. From 1971 to 1985, residual solids from the catalyst plant were settled in the ponds. From 2000 to 2003, the ponds were used to settle lime solids from the magnesium hydroxide production and grit consisting primarily of insoluble limestone, lime and silica from the use of purchased lime.

From 1982 to 2005, Dow recovered lime solids from the South Pond and sold them as agricultural liming material. The residual solids were primarily calcium and magnesium carbonates. Generally, residual solids were removed every approximately every 3 to 5 years and stockpiled on land inside an earthen-diked area north of the South Pond, typically referred to as the Lime Laydown Area (LLDA). The solids were air dried and transported offsite by a third party. This program was managed under the Michigan Department of Environmental Quality (MDEQ) Surface Water Management Division Program for Effective Residual Management (PERM). The program was transferred to the MDEQ Office of Waste Management under Part 115 – Rules for Solid Waste Management. In 2002, Dow requested and received approval for the residual solids be classified as 'site and source separated' in accordance with Part 115. As Dow's operations changed over time, significantly less residual solids were generated and sales of agricultural lime were discontinued in 2005.

The present day South Pond covers approximately 90 acres and is comprised of active (Center and Tertiary) and inactive (East, West, and Secondary) cells. The active retention cells provide four components of treating post-process water:

- Solids settling
- Heat loss
- Ammonia volatilization and reduction
- pH reduction

Currently, post-process water enters the Center Cell through a pipeline that discharges at the northern end of the cell (influent) and then flows to the southern end of the Center Cell. Water from the Center Cell flows by open channel to the Tertiary Cell and then continues through to the Polishing Cell. Water in the Polishing Cell (effluent) then is pumped back to the facility where it is combined with other wastewater before being discharged to Pere Marquette Lake through Outfall 001 (regulated under the facility's current National Pollutant Discharge Elimination System [NPDES] permit). Figure 4 provides an aerial view of the current pathway post-process water takes through the pond system. Figure 5 provides a series of historical aerial photographs that document the changes of the South Pond from preconstruction in 1951 to its 1993 status.

South Pond Construction

The South Pond was constructed in 1962 using dredged material (sands and organic sediments) from Pere Marquette Lake to create a pond perimeter access road around the prescribed area set aside for pond construction. Surrounding dikes were built using lime solids and fly ash, and raised approximately 10 feet above lake level. At that time, the pond was constructed as a single cell. In 1969, a new cell (presently called the Tertiary Cell) was created inside the southwestern corner of the original pond cell.

The dike walls were raised approximately 6 feet in 1972, using lime solids and fly ash from the pond interior. In 1975, the dike walls were widened approximately 8 to 12 feet, again using lime solids and fly ash from the pond interior. Dike walls were raised in 1980 (approximately 5 feet). Interior dike walls were constructed in the late 1970s to divide the large primary cell into four smaller cells, creating the West, Center, East, and Secondary Cells that can be seen today (Figure 4). A graphical representation of the South Pond dike construction is presented on Figure 6.

In 20017, Dow estimated the volume of solids that have accumulated in the South Pond at 1.7 million cubic yards, which includes solids in the West, Center, East, Secondary, and Tertiary Cells.

Figure 7 provides a north-south cross-sectional view of the South Pond and shows the approximate thickness of lime solids and position of the dike walls, relative to the surrounding surface water bodies. It also provides a view of the native post-glacial soils that lie beneath the pond solids.

In 2013, a vegetative cover was installed on the 10 acre West Cell. The cover was recontoured with a 6-inch sand grading layer/capillary barrier and 12 inches of topsoil seeded with an assortment of upland, native prairie species. Eight small perennial wetlands totaling 1.2 acres also were installed using a polyvinyl chloride liner over a 12-inch-thick topsoil layer. In summer 2014, additional larger woody species will be planted in areas with deeper soil and wetland plants. Details of the West Cell cover are in the *West Cell Construction Completion Report* (CH2M HILL 2013).

Characterization of Solids

In 1979 and 1997, Dow sampled several pond and dike wall cores to determine the thickness and make up of residual solids within the pond cells and surrounding dikes. The 1979 cores confirmed that the southern and eastern dike walls were primarily comprised of lime and fly ash fill. The 1997 cores, collected from the interior of the West, East, Center, Secondary, and Tertiary Cells, confirmed the lime solids are comprised of white and gray agricultural-grade lime. In addition, several of these 1997 borings penetrated into the native sand and peat beneath the pond cells. The results of the 1979 and 1997 coring activities are summarized on Figure 6.

Dow analyzed solids as part of the processes for evaluating their reuse as agricultural lime. The solids primarily consist of calcium and magnesium hydroxides and carbonates. No volatile organic compounds (VOCs) or semivolatile organic compounds (SVOCs) were detected in the samples analyzed. Samples also were analyzed by the toxicity characteristic leaching procedure (TCLP) for metals, VOCs, and SVOCs and were classified as nonhazardous (Dow 2001, 2002).

The residual solids within the inactive East and West Cells were further characterized in a geotechnical field investigation performed by CH2M HILL in 2011. The primary purpose of the 2011 investigation was to obtain data on the geotechnical properties of the lime solids within, and the soil beneath, the East and West Cells, including material composition and depth, unit weight, and strength properties, for use in determining stability of the residual solids during the West Cell cover design (CH2M HILL 2011).

As part of the geotechnical investigation in 2011, four borings were completed in the West and East Cells. The four borings in the West Cell identified the residual solids as brownish-white to white in color, and field classified them as silts that were soft to very soft in relative density. West Cell residual solids extended to approximately 15 to 19 feet below ground surface (bgs), with the native soils beneath identified as silty sands, with some locations exhibiting a black organic layer (approximately 1 foot thick) between the residual solids and the native soil. The residual solids recovered from the four borings in the East Cell were similarly classified as brownish-white to white silts with a soft to very soft relative density. East Cell residual solids were approximately 9 to 13 feet thick, with native soils comprising a black organic silt (approximately 1 to 2 feet thick) overlying sandy silty/silty sand. Based on the geotechnical measurements taken from these residual solids and underlying soils (specifically soft density and high moisture content), it was determined that these areas would exhibit settlement if cover materials were applied.

Environmental Characterization

The potential environmental impacts of the South Pond on local groundwater and surface water have been evaluated recently by completing several field investigations and annual sampling events. Since 2003, groundwater beneath the South Pond has been monitored annually for chloride and total dissolved solids (TDS). Data collected from these sampling events indicate elevated concentrations of chloride and TDS are present in groundwater beneath the perimeter areas of the South Pond. The concentrations are greater than MDEQ Part 201, Public Act 451 drinking water criteria (for chloride, at 250 milligrams per liter [mg/L]) and groundwater-surface water interface (GSI) cleanup criteria (for TDS, at 500 mg/L). Groundwater collected from beneath South Pond (from both the shallow and deep aquifers) in 2013 had chloride concentrations ranging from less than 2 mg/L up to 2,220 mg/L, while TDS ranged from 188 to 4,920 mg/L, and ammonia (un-ionized) ranged from 0.01 to 8.01 mg/L.

In April 2008, a pore water field investigation was performed to evaluate the presence of elevated chlorides and TDS in groundwater beneath the South Pond and other areas of the Plant Site. This study focused on surface sediments in Pere Marquette Lake and Pere Marquette River. Specifically, this study evaluated chloride concentrations at various depths within shallow sediment pore-water. Results of this pore water study relative to the South Pond indicated that in all five locations sampled, there were elevated chlorides in pore water above 250 mg/L in the upper 32 inches of sediment. In two of the five locations sampled, chloride exceeded the proposed MDEQ aquatic final acute value (FAV) in the same depth interval (CH2M HILL 2008).

In 2008, an exfiltration study was initiated as a result of a permit condition under OxyChem's NPDES permit. The primary goal of the exfiltration study was to determine if the South Pond was leaking. If the pond was determined to be leaking, the study was to determine the rate of exfiltration and mass loading of ammonia, chloride, TDS, and total Kjeldahl nitrogen (TKN) from the South Pond. This first phase of the exfiltration study took place from August to September 2008, and included completing cone penetrometer test (CPT) soundings, groundwater grab sampling, pond water sampling, and pond volume and flow measurements. The results of this study indicated the pond system was losing approximately 520 to 580 gallons per minute (gpm), and that the mass loading of chloride to shallow groundwater was within the total allowable discharge limits of the existing NPDES permit. In addition, the CPT soundings indicated the lake clay aquitard, which is present under Pere Marquette Lake, was not continuous beneath the South Pond, and that there are some areas with impacts in the deeper groundwater beneath the ponds (CH2M HILL 2009).

In 2009, a second phase of the exfiltration study was performed. The goal of Phase II was to assess the impacts of ammonia, chloride, and TDS in the deep groundwater and evaluate the hydraulics of the upper and lower aquifers beneath South Pond cells to determine if these impacts could migrate offsite. This was done by expanding the network of groundwater monitoring wells beneath the South Pond. Seven deep and four shallow monitoring wells were added to the site, several nesting with existing wells. This study concluded that shallow groundwater is discharging toward the surrounding Pere Marquette River and Pere Marquette Lake, while deep groundwater is upwelling to the shallow aquifer along the Pere Marquette River on the northern side of the South Pond. It also was found that ammonia exceedances were present in deep groundwater beneath the entire South Pond (CH2M HILL 2010). Figure 7 provides a cross-sectional view of the South Pond that identifies the general stratigraphy beneath the site upon completion of Phase II.

In 2012, a third phase of the exfiltration study was executed. This phase was tasked with determining if exfiltration water from the South Pond is migrating to areas beyond the Pere Marquette River and Pere Marquette Lake, and to further understand the fate of groundwater beneath the ponds that is affected by exfiltration losses. This was accomplished by employing a variety of hydraulic measurement tools. Seven additional monitoring wells (shallow and deep) were installed on the northern side of the Pere Marquette River (Figure 8). Hydraulic pressure differential measurements were collected in Pere Marquette River and Pere Marquette Lake around the perimeter of the South Pond to identify potential areas of groundwater seepage. Based on these results, seepage meters were deployed to quantify the rates of groundwater seepage to surface water. Phase III concluded that shallow and deep groundwater on the northern side of the South Pond discharges to Pere Marquette River and Pere Marquette Lake and that hydraulic pressure differential and seepage measurements confirmed groundwater is venting to surface water. Ultimately, these lines of evidence indicate exfiltration water from the pond system cannot be migrating beyond Pere Marquette River and Pere Marquette Lake (CH2M HILL 2012). Figure 9 presents the general understanding of the conceptual site model following Phases I, II, and III of the exfiltration study.

Annual groundwater monitoring continues at the site, with the most recent sampling event occurring in April 2014. The wells are analyzed for ammonia, chloride, and TDS. Beyond annual groundwater monitoring, no other environment assessment work is planned for the South Pond at this time.

References

CH2M HILL. 2008. *Alternative Closure Study 2008 Summary Report.* December.

CH2M HILL. 2009. *Dow Ludington Plant Site, 2008 Exfiltration Study Report.* February.

CH2M HILL. 2010. *Dow Ludington Plant Site, Exfiltration Study Groundwater Field Investigation Report. March.*

CH2M HILL. 2011. *Geotechnical Feld Investigation Results Memorandum. February.*

CH2M HILL. 2011. *West Cell Cover Design. March.*

CH2M HILL. 2012. *Ludington Plant Site Exfiltration Study, Phase III – Field Investigation. October.*

CH2M HILL. 2013. *Construction Completion Report West Cell Cover Construction, Ludington Plant Site – South Pond. March.*

Dow 2001, Facsimile from Dow to MDEQ, Subject: Information on Agricultural Lime Materials, November 9, 2001

Dow 2002, Letter from Dow to MDEQ, Subject: Total Metals Analysis of Agricultural Liming Residuals, March 5, 2002

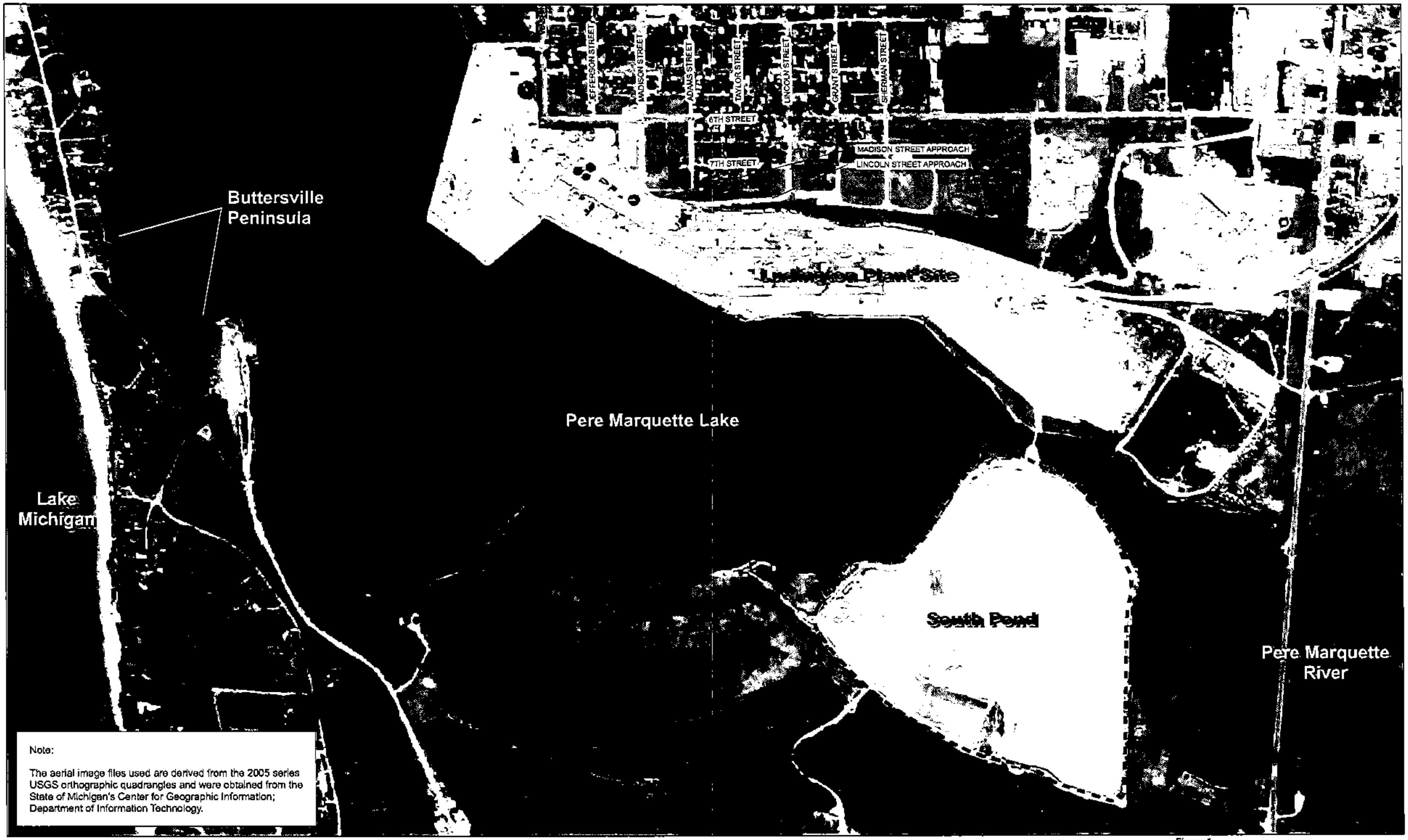

Figure 1
Ludington Plant Site Map
South Pond - History and Investigative Summary
Ludington Plant Site
The Dow Chemical Company
Ludington, MI

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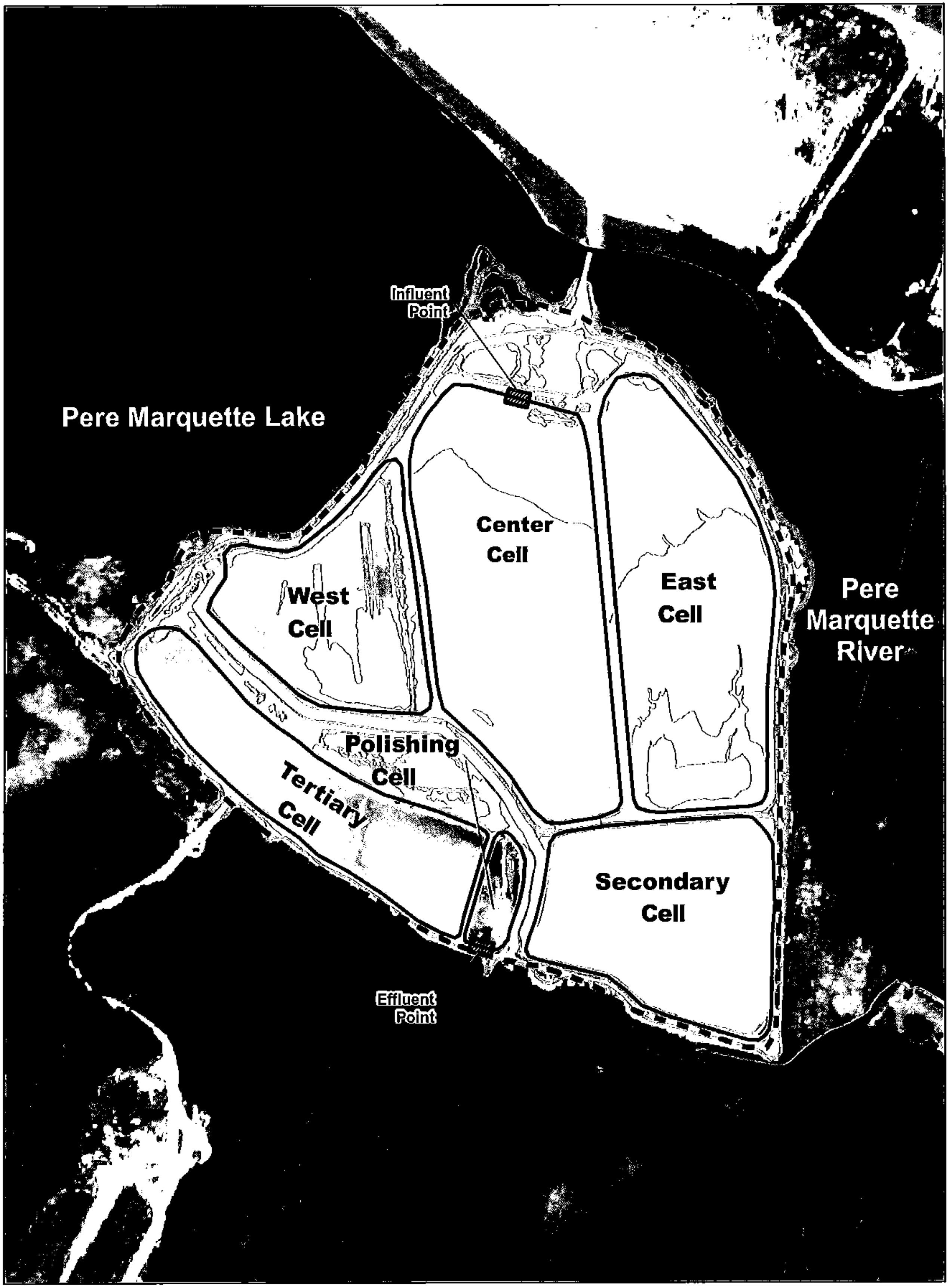

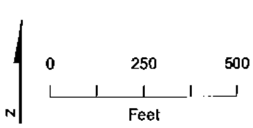

Figure 2
South Pond Site Map
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